A Proposed RFID Wireless Body Sensor Mesh Network using Intelligent Agents and Cloud-based Architecture

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ABSTRACT

Every year, thousands of patients in Caribbean healthcare facilities are held in various departments for medical observation, which involves the monitoring of the patient's physiological condition by medical staff, i.e. duty nurses and doctors. Patient monitoring is done manually and or using Wireless Body Sensor Networks (WBSN) that are pyhsically monitored by medical staff. In this paper, we propose a system for patient monitoring using Wireless Body Sensor Mesh Networks (WBSMN) that utilize Radio Frequency Identification (RFID) sensors for reading physiological parameters and positive patient identification. Intelligent Agents are proposed for querying sensor nodes, data aggregation and alerting medical staff of anomalous readings. A Cloud-based architecture is also proposed for supporting a community of healthcare centers and remote / mobile patient monitoring.

Keywords: Patient Monitoring, Wireless Body Sensor Mesh Network, Radio Frequency Identification, Agent Technology, Cloud Computing

1. INTRODUCTION

The field of healthcare has been the focus of many research initiatives over the past years. Many of these projects have focused on the use of Information and Computing Technology (ICT) within the healthcare industry, to improve efficiency in administrative, medical, and technical processes. There are many problems within the sector and the issue of patient monitoring has attracted a lot of attention over the past ten years.

Patient monitoring is a critical function, since the condition of a patient under medical observation can change in the blink of an eye. In critical cases, it is necessary to remove, or reduce significantly the possibility of human error. ICT offers many innovations that seek to reduce this probability. Manual patient monitoring, however, requires that medical staff, such as a nurse or doctor, make routine checks on a patient under observation, to capture the physiological conditions of the patient such as temperature, blood pressure, pulse rate, etc. The readings are recorded on the patient's medical chart; this captured data is then used to determine the patient's treatment plan. ICT innovations not only make the automation of the patient monitoring process possible, but may also significantly improve the process.

In this paper, we propose a solution to this problem, which we will deploy in the Jamaican context. However, we recognize the generic nature of the solution and the fact that it can be applied in many other contexts. We start by surveying the related work in the space, then present our solution and then conclude.

2. RELATED WORK

This work intersects the areas of Wireless Sensor Networks (WSNs), Radio Frequency Identification (RFID) Technology, Agent Technology and Cloud Computing.

2.1 WIRELESS SENSOR NETWORKS (WSN)

Wireless Sensor Networks (WSN) (Singh et al., 2010) were initially developed for military applications, such as battlefield monitoring, and have been successfully retargetted for patient monitoring. Researchers have found that wireless sensors when operated in ad-hoc environment are susceptible to frequent network failures and are also unreliable (Sankaranarayanan and Ganesan, 2009). Failures are not acceptable within a healthcare environment where critical information about the patient is being transmitted. To provide a more relaible network, researchers have proposed the use of Wireless Mesh Networks (WMN) (Sankaranarayanan, 2008, Sankaranarayanan and Ganesan, 2009), which are an extension of Local Area Networks (LANs). WMNs have a far better range and also use a limited amount of cabling (Akyildiz et al., 2005). WMNs enables the sensing of vital information arising from wireless sensors connected to the backbone network, creating a Wireless Sensor Mesh Network (WSMN) (Sankaranarayanan, 2008, Sankaranarayanan and Ganesan, 2009) which is an integration of wireless sensors and mesh network providing different functionalities to improve the monitoring of the environment where the network is deployed. All WSNs are controlled by software that implements the various routing protocols that maybe used on the network. The software that controls the interaction between the sensors in the network is another area in which research is ongoing; as such researchers have proposed the use of intelligent software as middleware for the WSN. The Internet of Things (IoT) (Castellani et el., 2010) is the natural progression of WSNs, where many physical objects are being connected to the Internet via wireless technologies, such as Near Field Communication (NFC) and Radio Frequency Identification (RFID).

2.2 RADIO FREQUENCY IDENTIFICATION (RFID)

Radio Frequency Identification (RFID) (Ahsan et al., 2010, Korkmaz et al., 2010, Lefebvre et al., 2011, Mitrokotsa and Douligeris, 2009, Rantzau et al., 2006) has the potential to be used not just for the monitoring of patients' physiological parameters, but also for management of medical equipment, dangerous medical substances and drugs, inventory control, and the identification and locating of patients. Morak and Schrer (2012) describe a RFID chip enabled card that allows patients to have their medical information read and even written to by physician even if the patient has undergone medical treatment in another hospital. Fifah (2013) presents a solution where RFID is used for patient appointment where a card is used for making appointment at hospital and patients served based on priority.

2.3 INTELLIGENT AGENT

Intelligent Agent Technology (IAT) was born from the field of Artificial Intelligence, which defines an agent as "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors", (Edwards and Sankaranarayanan, 2011). The authors proposed IAT for searching and making appointments at various healthcare facilities based on the patients current health condition. In their paper, intelligent agents were created using the Java Agent DEvelpoment platform (JADE), enhanced with the Lightweight Extensible Agent Platform (LEAP) add-on and deployed on mobile devices (e.g. smart phones, PDAs) in the Jamaican healthcare environment.

2.4 CLOUD COMPUTING

Cloud computing seeks to present to users all the Information Technology (IT) resources as "Pay-Per-Use" services. Currently, there are three (3) primary services available via the Cloud, namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Given this, a health care service only needs a good internet connection and REST-like infrastructure to leverage Cloud technology. This enables small healthcare clinics to multi-specialty hospital in an arbitrary country to pay per (cloud) service, similar to paying for Internet service. Research has been carried out towards a cloud-based electronic hospital management system (Horowitz, 2012) using an application program interface that connects emergency department workers with pre-hospital data from Boston EMS ambulances. Doctors at Beth Israel Deaconess Medical Center (BIDMC) are

allowed to see vital data collected in ambulances via the hospital's Emergency Department (ED) Dashboard and import it into patient's Electronic Health Records (EHRs). Before this project was implemented, the doctors in the ED had to fax the patient data record manually to the BIDMC every day for their references and data storage. Following this another research project was carried out, employing Cloud computing for storing every patient's health record of different hospitals in country that can be accessed from mobile by nurse and doctor from any hospital towards medication. Patients also did not need to carry the information around with them and the hospital did not need to have a dedicated database server (Sarina, 2013).

3. THE PROPOSED SYSTEM

We propose to employ RFID Wireless Body Sensor Integrated Mesh Network with Cloud-based intelligent Agents to enable seamless and more efficient patient monitoring.

Based on our literature review, healthcare facilities currently employ the use of Wireless Body Sensor Networks (WBSN) to monitor patients and these WBSNs are normally formed in an ad-hoc fashion, which is prone to failures. We propose to use a Wireless Body Sensor Mesh Networks (WBSMN) in our system (Figure 1) to provide far better range and bandwidth as posited by Sankaranarayanan (2008). An additional advantage of our system is that the performance will be acceptable or marginally better or WSBNs; this is supported by Benjamin and Sankaranarayanan (2009) experiments using the Opnet Simulator.

Our next distinct contribution lies in the integration of WBSMN and RFID technologies to create a RFID Wireless Body Sensor Mesh Network (RFID-WBSMN), which would see the RFID Tag and Interrogator enhanced by the inclusion of sensors for monitoring the physiological parameters of the patient and positive patient identification.

We also propose using intelligent agents at the mesh node in the RFID-WBSMN towards querying the sensors and taking intelligent decision in reporting to medical staffs' smart handheld devices in case of anomalous readings. The literature has reported on the increased performance of wireless sensor networks (WSN) when agent technology is used as supporting middleware, since the agent can be programmed to perform some processing work on the sensed data, which can lead to a reduction in the network traffic therefore reducing network latency. The processing of these physiological parameters data by means of middle ware (i.e. intelligent agents), requires the use of powerful computer systems with memory, processing power and software. Therefore a Cloud-based architecture is proposed, which would represent a Community Cloud; the Community cloud is under the control of multiple organizations that share some common interest (e.g. health care facilitates). The infrastructure, platform and software for the proposed system will be managed by Cloud Service Provider (CSP), which can be accessed and used by a range of healthcare entities.

Figure 1 shows the proposed system and the various components; the system has four intelligent agents namely the Patient Agent (PA), Aggregator Agent (AA), Nurse Agent (NA) and Doctor Agent (DA). The PA is located at the cluster head of the RFID-WBSMN of the patient and queries the sensors for data and transmits to the AA. The AA is located at the Base Station, i.e. a workstation connected to the wired network with internet connection The AA checks for indications of anomalous readings sent by the PA, then initiates alerts to the NA and DA of the on-duty medical staff and also the DA of the patient's assigned doctor (who may not be on duty). The AA transmits the patient's data to the cloud-based application server for final processing and storage in the database server. The NA and DA are located on the smart handheld device for the on-duty nurse and doctor respectively (and also the patient's assigned doctor who may not be on duty). The NA and DA provide alerts to the medical staff and also allow the querying of patient's status, which includes current and past sensor readings.

The proposed system will be extended to support mobile or remote patients, using PAs located on smart handheld devices capable of receiving and transmitting readings for the sensors monitoring the patient's physiological

condition. Using the cloud services, the data from the mobile or remote patient will be processed and the monitoring healthcare facility and medical staffs alerted of abnormal conditions.

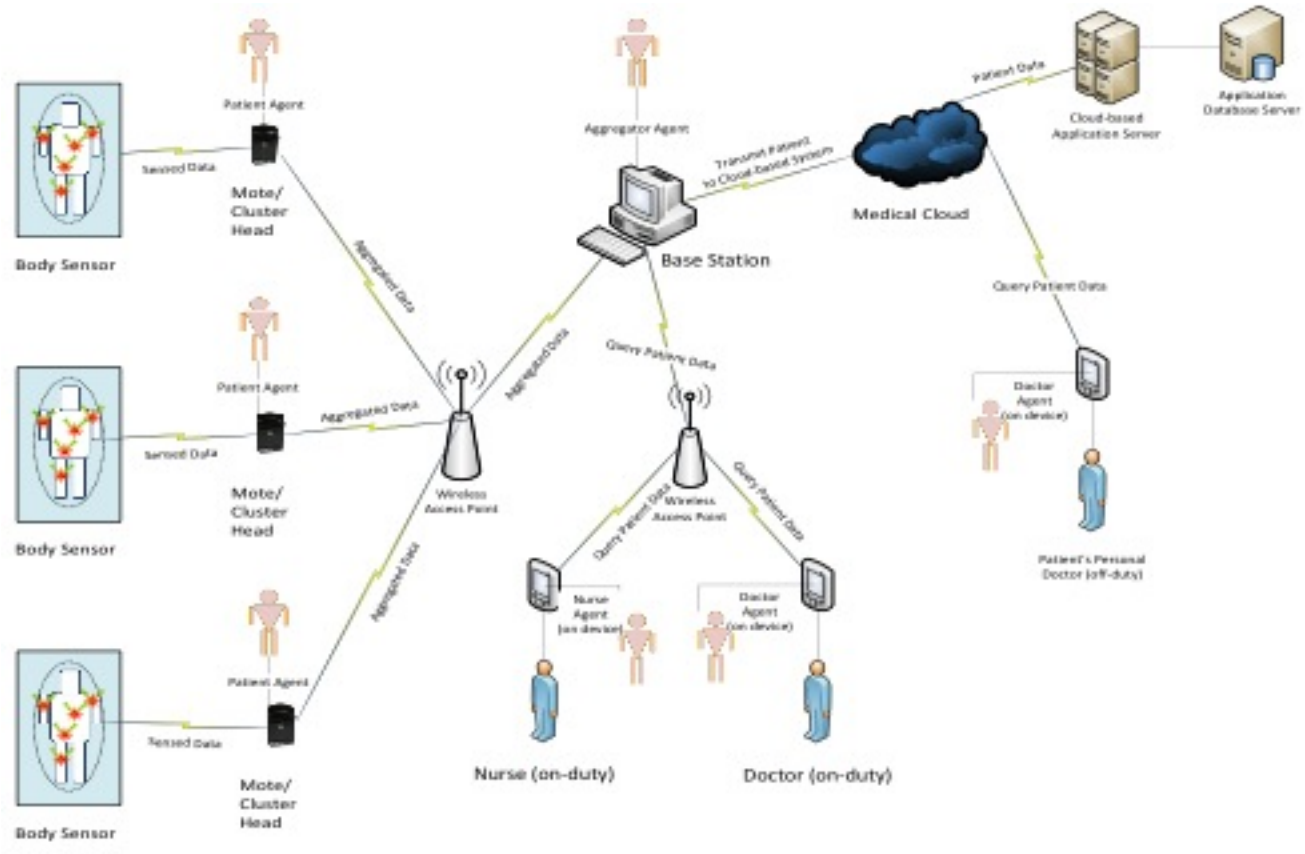

Figure 1: Proposed System Architecture

This proposed system can be viewed as an Internet of Things Medical (IoT-Med), as it is possible to uniquely identify, track and monitor all the "things" connected to the system over the Internet.

4. CONCLUSION

We propose the integration of RFID with the WBSMN, to develop a sensing network that can uniquely identify the patient and the data collected from the patient, in addition to determining the patient's location within the network. This research will also leverage Cloud Technology to address the concerns of feasibility of system implementation, dissemination of patient's data via the Internet, and also remote monitoring of patients by any healthcare service. This research will introduce the use of intelligent agents within the Cloud for the intelligent autonomous management of health care applications for patient monitoring through a cloud-based infrastructure, platform and software to be accessed and used as pay per service. This research seeks to provide a ubiquitous system for patient monitoring both within the health care facility and at remote locations. We propose to test this system in a hospital in Kingston, Jamaica.

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